CAREER: Nanostructured Intermetallic Alloys - Annealing Behavior, Microstructural Control and Influence of Scale in Reversibly Ordering Systems

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The Role of Polytwin Boundaries for Properties of Ferromagnetic FePd

➢ Aim - Study the competition of ordering transitions to $L1_0$ & $L1_2$ intermetallic phases with recrystallization during annealing after cold-work of $Fe_{50}Pd_{50}$ & Pd-rich Fe-Pd alloys, which are used as model systems.

➢ Polytwin (PT) boundaries play an important role for mechanical and magnetic behavior of conventionally processed $L1_0$-FePd. *Transmission electron microscopy* (TEM) of deformed $L1_0$-FePd revealed the fundamental mechanisms of shear transfer across the PT-boundaries. *The dislocation based shear transfer model mechanism rationalizes the plastic flow behavior of ordered $L1_0$-FePd.*

➢ Combined Reaction Processing exploits the competition between *recrystallization* and the *ordering transition* during annealing of Fe-Pd alloys. It promises to enable microstructural control to taylor magnetic and mechanical properties. FePd and other *uniaxial ferromagnetic* $L1_0$-ordered phases are considered for the next generation of data storage technologies & hybrid MEMS/NEMS devices.

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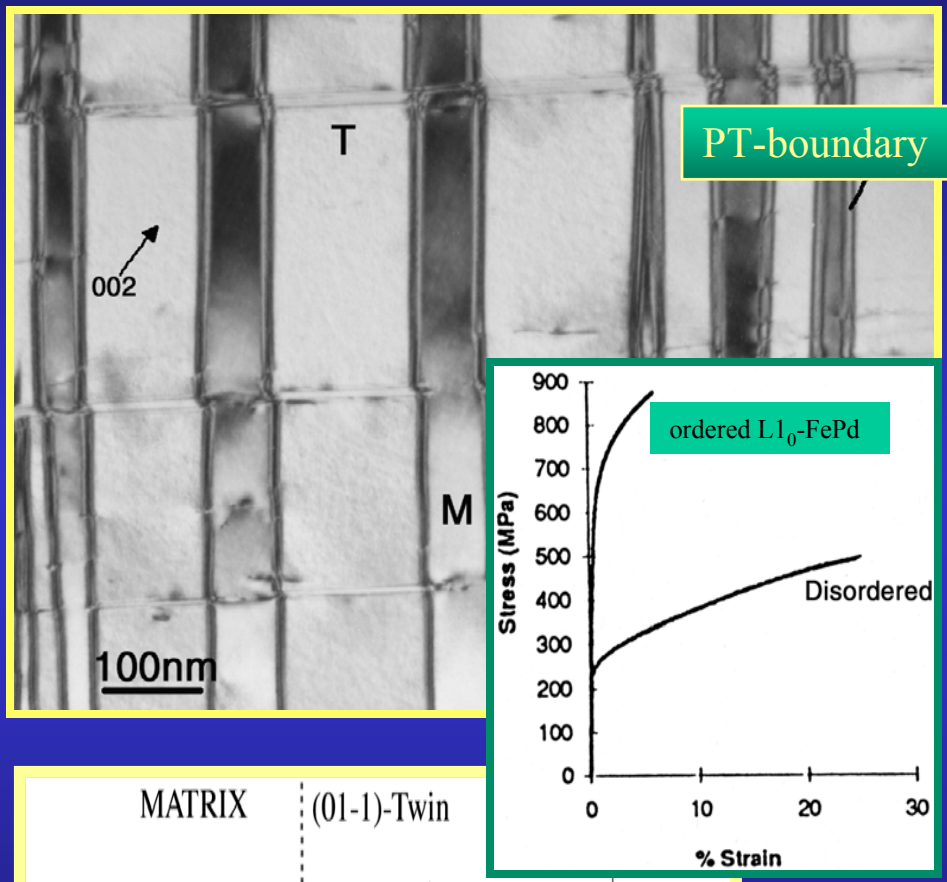
J.M.K. Wiezorek, "Dislocation and Twin Interactions with Polytwin Interfaces in $L1_0$-ordered Intermetallics", Submitted to *Intermetallics*.



This program of research focuses on processing-structure-property relationships in functional intermetallics. It uses combinations of thermal analysis by DSC and microstructural studies by TEM, SEM and XRD together with mechanical and magnetic property measurements to investigate the fundamentals of the annealing behavior of reversibly ordering systems, which are represented by selected $L1_0$- and $L1_2$-ordering Fe-Pd alloys as model systems. Exploiting the competition between the ordering transformation and the recovery and recrystallization reactions during annealing of heavily cold-worked (using ECAP) Fe-Pd alloys nanoscale microstructures (grain sizes < 500nm) with superior mechanical and magnetic properties are being produced.

Reversibly ordering intermetallic systems are used for challenging structural applications (e.g. gas-turbines, jet-engines, car-engines) and also for functional applications (magnetic data storage, switching, actuation and as components in novel spintronics based devices). The FePd alloys used as model systems here are a member of a group of $L1_0$-ordered, uniaxial, high magnetocrystalline anisotropy materials that also includes FePt, CoPt and MnAl. These $L1_0$-ordered ferromagnetic phases exhibit good corrosion resistance and mechanical strength, as well as superior magnetic properties that promise data storage density increases by 2 to 3 orders of magnitude (Terra-bytes per sq-inch) and are also very attractive for MEMS/NEMS hybrid microdevices as active components and as magnetic power supplies.

The identification of the salient features of the deformation behavior of FePd is the foundation for the development of an understanding of the behavior of FePd during deformation processing and the details of important microprocesses during annealing, which ultimately control microstructural evolution and determine technical properties.

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➢ International student exchange program with Materials Physics program of University of Augsburg, Germany;

→ Summer 2002: 2 U.Pitt undergrad's to Augsburg;
3 U.Aug'g undergrad's to Pitt'gh.

➢ REU Summer 2002:

→ 1 female and 1 male physics undergraduate recruited for MSE REU through presentation in EngPhys seminar.

➢ Senior Design Project, Acad. Year 2002:

→ 2 undergraduates designed, built & tested equal-channel angular press (ECAP) for severe plastic deformation pressing (SPD) of Fe-Pd alloys.

EDUCATIONAL:

4 undergraduates...
David Driggers & Kevin J. Seidel (ECAP Design and Testing)
Anne Smith & Paul Ohodnicki (REU-student summer 02)

2 graduate students …
Amal Al-Ghaferi (female from UAE) and
Anirudha Deshpande (male from India)

2 post-docs… Huiping Xu (partly NSF supported, since 05/01)
Helge Heinrich (partly NSF supported, 06-10/02)

⇒ 90˚ & 120˚ die configurations, 36mm^2 square cross-section
⇒ Single pass ECAP of Al-alloy with 90˚ die
⇒ Single pass ECAP of Al-alloy & FCC-FePd with 120˚ die

FePd billet single pass 120˚ die
=> doubled hardness

During the REU program and as part of the International Exchange program the graduate students have opportunity to engage in training of the undergraduate researchers and teach them research techniques. Experimental skills acquired by the graduate students and passed on to the undergraduate students include vacuum arc-melting of Fe-Pd alloys, sample preparation for microstructural analyses using SEM, TEM and XRD, as well as mechanical property determination by hardness and tensile testing and magnetic behavior studies using magnetometry. The students thermally and mechanically process alloys by heat treatments, rolling and equal-channel angular pressing. Through daily discussions and by-weekly formal group meetings students investigate and develop an understanding of sophisticated processing-structure-property relationships in advanced ferromagnetic intermetallics.

The exchange program with the Materials Physics degree program at the University of Augsburg has been initiated together with Dr. W.A. Soffa and sees its first groups of undergraduates participating in 2 month long research visits to the respective partner institution. The German students will work on microstructure-property relationship studies in the processed ferromagnetic FePd alloys.

Improvements to the design of the ECAP facilities are devised as the students continue to utilize this student-built facility for the severe plastic deformation processing of nanocrystalline FePd ferromagnets.